that the coincidence is not accidental, but represents the separation of three distinct types of wave motion having different rates of propagation.

On plotting the records it is found that the time curves of the first two phases form curved lines, indicating an increase of apparent velocity with distance from the origin, such that, applying Rudzki's investigation, the wave motion represented by these two phases must have travelled through the earth, along curved wave paths, convex towards the centre of the earth, and with a rate of propagation which increases with the distance from the surface. On continuing these curves, by extrapolation, to the origin they give rates of propagation in very fair concordance with the rates of propagation of condensational and distortional plane waves which may be expected to obtain in continuous rock at some distance from the surface of the earth.

The waves of the third phase show no such increase of rate of progagation with distance from the origin. The rate of propagation is uniform at all distances; from which it is concluded that the great undulations of the third phase are surface waves, travelling with a uniform rate of propagation round the surface of the earth. It is also found that the waves of this phase set up by great earthquakes travel faster than those set up by lesser ones, and from this it is concluded that the rate of propagation of these waves is in some way a function of their size, thus affording a confirmation of Lord Kelvin's suggestion that their propagation is in part gravitational.

The general conclusion is that in the complete record of a distant earthquake, three distinct types of wave motion can be recognised (1) condensational, and (2) distortional plane waves, travelling by brachi stochronic paths through the earth, and (3) elastic, or gravitational elastic, surface waves, travelling round the surface of the earth. The records are, however, often incomplete by the omission of the first or the first and second of these phases, and the widely divergent estimates of the apparent rate of propagation of the preliminary tremors are largely due to this.

"The Medusæ of Millepora." By Sydney J. Hickson. F.R.S.

Received November 7,—Read November 23, 1899.

Since the discovery of male medusæ in specimens of Millepora collected by Professor Haddon in Torres Straits eight years ago (2), I have examined several large collections of specimens, both dried and preserved in spirit, from different parts of the world with the object of comparing the medusæ and the ampullæ they form in the varying forms which the genus exhibits. The examination of the dried coralla in museums has convinced me that the presence or absence of ampullæ

cannot be used as the diagnostic character of any one species, since these structures occasionally occur in nearly all the principal forms of the genus which have been described. It was not until I examined one of the many specimens of the genus collected by Mr. Stanley Gardiner in Funafuti, however, that I had the opportunity of seeing again a male medusa, all the other specimens I had received having proved to be barren. The male medusæ of Mr. Gardiner's specimen turned out to be identical in size and form with those given to me by Professor Haddon, and I came to the conclusion that no specific distinction could be drawn between the two forms based on characters of the medusa before it is set free (3).

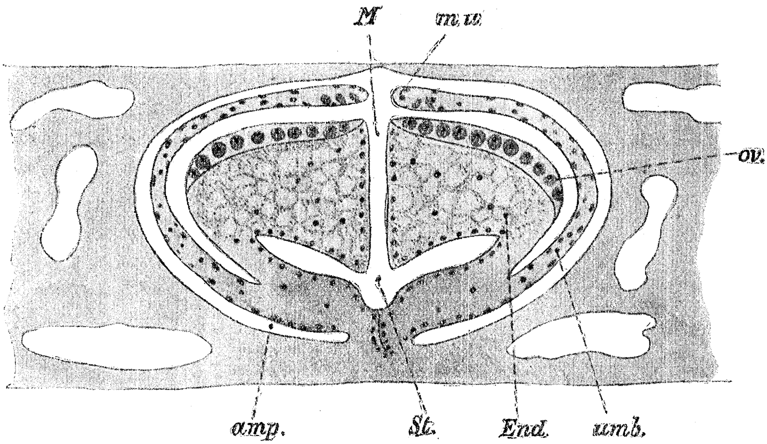
In May, 1898, Mr. Duerden, of the Jamaica Institute, sent me a small piece of Millepora preserved in spirit, which upon examination was found to bear female medusæ. Each of these medusæ carried on the manubrium from thirty to fifty ova of approximately equal size, 0·015 mm., and the general appearance of the medusæ suggested that they were nearly ready to escape. This appearance, however, proved to be deceptive, for in December I received another consignment of the material from Jamaica, in which the medusæ showed very different characters, three or four, or, in a few cases, five, of the ova in each medusa being greatly enlarged and the others degenerate. In the meantime, Mr. Duerden wrote to me saying that he had actually seen these medusæ escape, and had been able to liberate many others from the corallum by means of a needle. Thus was it definitely proved that this Millepore in the West Indies produces free swimming medusæ which bear ova.

Several important questions arose when this matter was settled. It was clearly important to find the male medusa of Millepore in Jamaica to compare it with the female medusa and also with the Pacific male medusæ. It was also important, if possible, to trace the development of the medusa, and to find, if possible, the place of origin of the sexual cells. In the hope of being able to get fresh material which would enable me to answer these and other important questions, I have delayed the publication of the results I have obtained for nearly twelve months, but as it seems probable that I may have to wait a very long time more before the material is forthcoming, I have decided now to publish the results of my investigation of Mr. Duerden's material.

1. *The immature female medusæ* received in May, 1898. A small branch of a Millepore well preserved in spirit after treatment with formalin was all that was sent to me. No very definite signs of the presence of the medusæ could be noticed before the specimen was decalcified, but as soon as the soft tissues peeled off the lower parts of the corallum under the action of nitric acid a considerable number of medusiform bodies could be seen with a lens. They varied consider-

ably in size, but the majority were about 0·4 mm. in diameter, and the remainder rather smaller. The structure of these bodies was examined by means of sections taken horizontally and vertically to the surface of the corallum. Each medusa (fig. 1) lies in an ampulla (amp.) or cavity in the corallum, and is attached by a narrow stalk to the centre of the innermost wall of the ampulla. The umbrella (fig. 1, umb.) is a thin

FIG. 1.

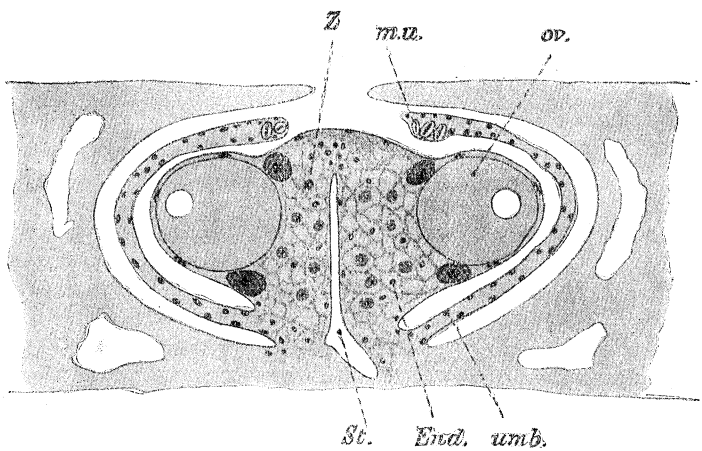


membrane, slightly swollen at the margin (m.u.). With a high power of the microscope it can be clearly seen that this membrane consists of a median lamella of endoderm, covered on each side by an ectodermal epithelium. No canals or cavities of any kind occur in the umbrella. There is no velum, and there are no tentacles. The cavity of the umbrella is almost completely filled with a swollen manubrium, which bears on its outer or upper side a mouth (M), around which lies a broad band of ova. There can be no doubt that in some cases there is communication between the endodermal cavity of the medusa and the sub-umbrella cavity by way of this mouth, but it is impossible to say in the present state of the inquiry whether the mouth of the medusa opens normally at this stage. It appears to be closed usually at the time when the medusa is ready to escape, as will be mentioned later on. The great size, however, of the manubrium of the female medusa is principally due to the thick vacuolated endoderm (end.). The gastral cavity of the medusa is not so simple as it is in the male medusa (of the Pacific Millepores), but it is subject to many very striking variations. In some of the medusæ there are four radial cœca proceeding a short distance into the endoderm of the manubrium from the main tubular gastral cavity that occupies the axis of the manubrium. This cavity communicates, on the one hand, with the exterior by the mouth,

and, on the other, with the canals of the cœnenchym. In some cases there are only three of these cœca, in others they are very irregular, and again in others there are none. It is quite impossible to determine with certainty what is the "typical" or "average" arrangement of the cavities of these medusæ with the limited amount of material at my disposal, but I think it is probable that the quadriradiate form will be found to be the most frequent of the many variations.

2. *The mature female medusæ* received in December, 1898. The material sent to me being abundant, I have been able to examine a large series of medusæ at this stage before their escape from the ampullæ. I have also examined a few medusæ which Mr. Duerden collected in his aquaria after their escape from the ampullæ. They are decidedly larger than the immature medusæ of the last collection; the diameter of the umbrella being about 0·6 mm. instead of about 0·4 mm. The variability is even more pronounced at this stage than

Fig. 2.



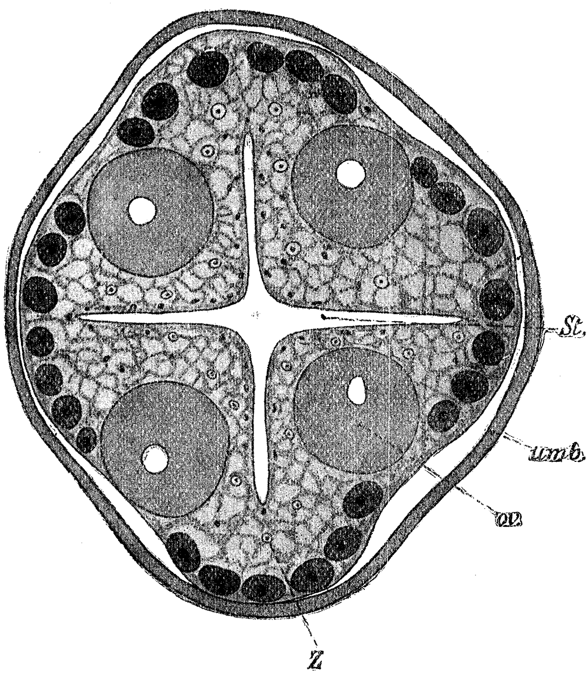
in the last, and it is almost impossible to find two medusæ exactly alike. In most of the medusæ (figs. 2 and 3) three or four large ova are found, and the manubrium is usually triradiate or quadriradiate accordingly, but occasionally medusæ with five, two, or only one mature ova occur, and the manubria of these are more irregular.

I mounted a piece of a decalcified specimen about 48 sq. mm. in area, and found that it bore forty-one medusæ; of these, nineteen had four ova, eighteen had three ova, two had two ova, one five, and one one. In another piece I counted three with four ova, six with three ova, and one with two. In another piece 15 mm. by 10 mm. in area I counted forty with three ova, fifteen with four ova, five with two, and five with

one. In this piece, however, I noticed that in one-third of the area the fours were about six times as numerous as the threes, while in the remaining two-thirds the threes were about nine times as numerous as the fours.

No very definite conclusions can be formed upon these figures, but it seems to me probable that so little is the form of the medusa of Millepora stereotyped, that a slight variation in the distribution of nourishment in the canals may be the determining cause of the medusa being triradiate or quadriradiate.

FIG. 3.



The germinal vesicle of each large ovum is regularly spherical in shape, with a very sharp outline. The nucleoplasm is apparently homogeneous, and resists the action of iron-hæmatoxylin and carmine, exhibiting no nucleolus nor chromatin granules.

In addition to the large ova, there are always present in the medusa several oocytes. These cells stain much more deeply than the ova, and many of them exhibit a well-defined nucleus with a deeply staining nucleolus. In some cases the cytoplasm of one of these cells may be seen to be continuous with the cytoplasm of an ovum, and I have little doubt that most of them, and perhaps all of them, are ultimately

absorbed into the substance of the large ova. The nucleus of the oocyte seems to be disintegrated before complete fusion takes place, since no degenerate nuclei can be found in the cytoplasm of the large ova.

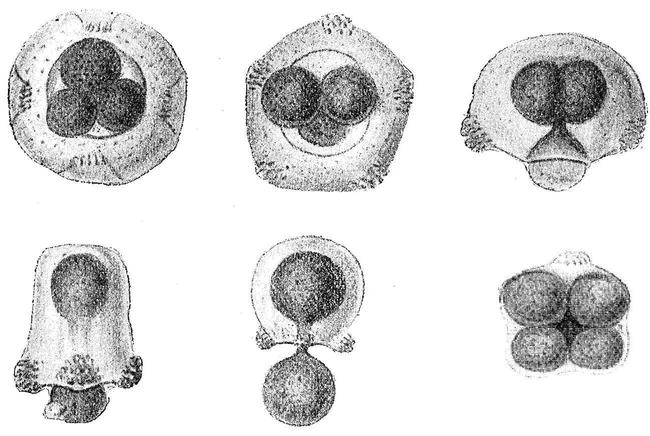
The remarkably thick endoderm of the female medusa is a very characteristic feature. It may be regarded as a special adaptation of endodermal tissue for the purpose of affording nourishment to the rapidly maturing ova, and similar in function to the trophodisc of the Stylasteridæ.

At this stage several zooxanthellæ (fig. 3, z) occur in the manubrium, but none were observed in the cytoplasm of the ova.

I have not been able to find evidence of the existence of an open mouth in the medusæ at this stage, but, bearing in mind the great variability they exhibit, I cannot assert that a mouth never occurs.

The margin of the umbrella exhibits three or four or five thickenings, due to clusters of nematocysts (figs. 4—9), but no definite tentacles nor sense organs were to be found after a most searching examination.

Figs. 4—9.

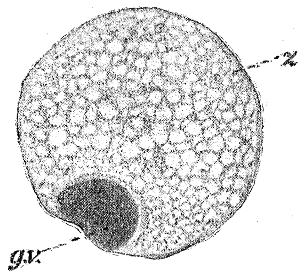


3. *The liberated medusæ.* I have carefully examined the medusæ and free ova that Mr. Duerden collected in the water of his aquarium. The medusæ are so shrivelled and degenerate that nothing of their anatomy could be satisfactorily determined. The ova, however, appear to be in a satisfactory state of preservation, and exhibit one or two features of interest. Each ovum of this series is approximately 0·25 mm. in diameter, that is to say, 0·05 mm. larger in diameter than the ovum in the last stage.

The cytoplasm is very granular and contains numerous vacuoles and a few zooxanthellæ (fig. 10, z). The germinal vesicle is very large

and contains no nucleolus and very few or no chromatin granules. Its outline is very ill-defined. The presence of zooxanthellæ in the ovum at this stage is of interest, and it is a matter for regret that I have been unable to determine the manner in which they pass into the cytoplasm from the endoderm of the medusa.

FIG. 10.



In general characters the free ovum of Millepora has a remarkable resemblance to the ova of Alcyonium and other Alcyonarians, and I believe that this points to the conclusion that its specific gravity is very slightly higher than that of sea water, and sinks extremely slowly when set free.

We are indebted to Mr. Duerden (1) for a brief account of these medusæ as observed in an aquarium (see figs. 4—9). "When first liberated their walls appeared quite wrinkled, and the interior was occupied with three or four opaque bodies (the ova). No stalked tentacles were developed, their place being taken by four or sometimes five swollen areas, where a few large stinging cells were located. The medusæ were very sluggish in their movements, feebly pulsating only now and again. While under observation a curious action began to take place; the opaque bodies in the interior were seen to be extended through the mouth of the medusæ" (*i.e.*, the mouth of the umbrella cavity), "sometimes singly, sometimes two or more partly connected. These became spherical, and appeared to have a slight movement of their own. Having discharged themselves in this way, the medusæ shrunk up and their mission was apparently ended. The whole process, liberation of the medusæ and extrusion of the spheroidal bodies, was completed in five or six hours."

There are almost insuperable difficulties in the way of maintaining a sea-water aquarium in the tropics in a thoroughly healthy condition. I am satisfied that Mr. Duerden took every possible precaution, but nevertheless it is probable that in some respects the conditions cannot be relied upon as being strictly normal. The observations, however, are of importance, the structure of medusa as it is seen in the ampulla

suggesting that it is not capable of living a long time free from the colony, and the character of the cytoplasm indicating that when the ovum is set free it is very buoyant, and is probably fertilised and passes through the early stages of its development suspended in the water.

It is almost certain that the medusa does not digest food and nourish the ova after its escape from the ampulla, and I am inclined to believe that after a few pulsations which are sufficient to carry it away from the region of the colony, the ova are set free and the medusa dies.

Correction.—In a former communication to the Royal Society (4), I described certain cells in the cœnosarc of Millepore from Celebes as ova. Since the discovery of the female medusa, I have carefully re-examined my preparations, and satisfied myself that I made a mistake. These cells are not ova, but the cells which ultimately give rise to the large kind of nematocyst.

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2. Hickson, S. J. "The Medusæ of *Millepora Murrayi*," 'Quart. Journ. Micros. Sci.,' 1891.
3. —— "Notes on the Collection of Specimens of the genus Millepora, obtained by Mr. Stanley Gardiner at Funafuti," 'Zool. Soc. Proc.,' 1898.
4. —— "The Sexual Cells and Early Stages of Development of *Millepora plicata*,' 'Phil. Trans.,' B, vol. 179.

"Vapour-density of Bromine at High Temperatures." By E. P. Perman, D.Sc., and G. A. S. Atkinson, B.Sc. Communicated by Professor Ramsay, F.R.S. Received November 14,—Read December 7, 1899.

It has been proved by one of us in a previous paper* that the vapour-density of bromine is normal up to a temperature of 279° C., a result in entire opposition to the numbers obtained by J. J. Thomson.†

We have now determined the densities at temperatures ranging from about 600° C. to 1050° C. by a modification of the former method, the chief difference being that the globe was not filled with the vapour by boiling out the excess of liquid, as in the usual method, but by admitting the bromine, already in the form of vapour, to the globe which remained in the furnace throughout the experiment.

Apparatus used.—A is a porcelain globe (fig. 1), in some experiments

* 'Roy. Soc. Proc.,' vol. 48, p. 45.
† 'Roy. Soc. Proc.,' vol. 42, p. 345.

FIG. 1.

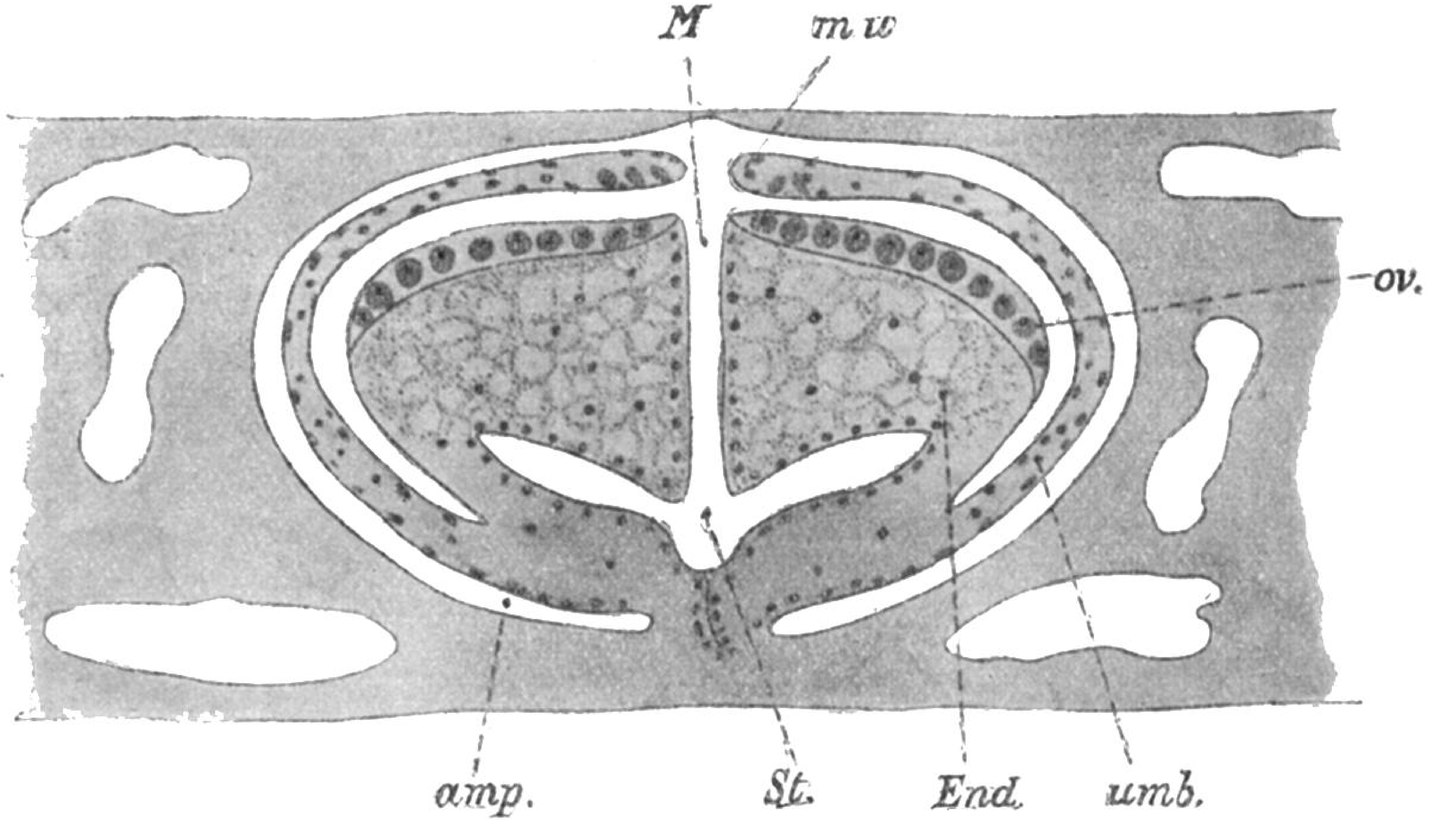


FIG. 2.

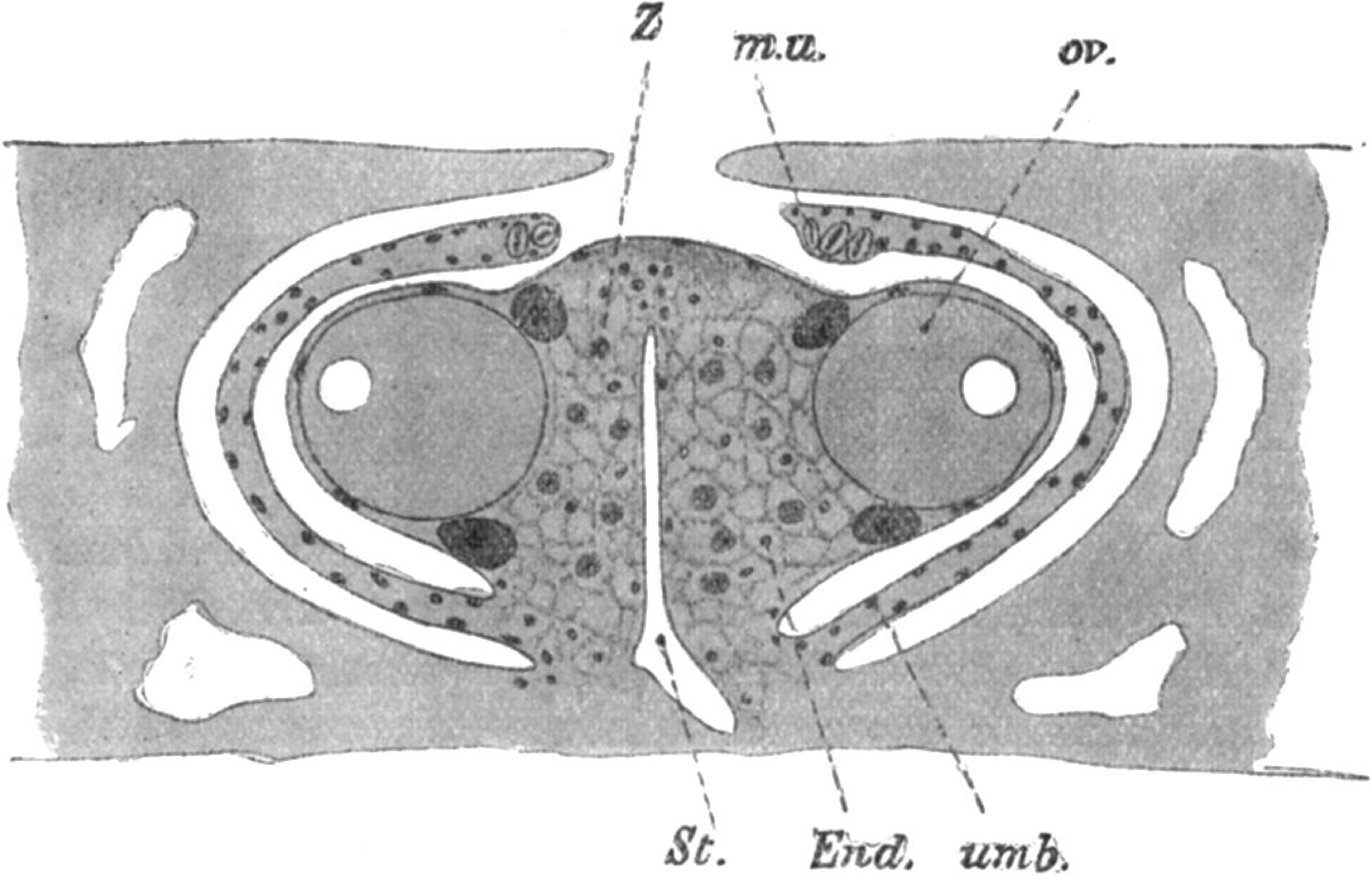
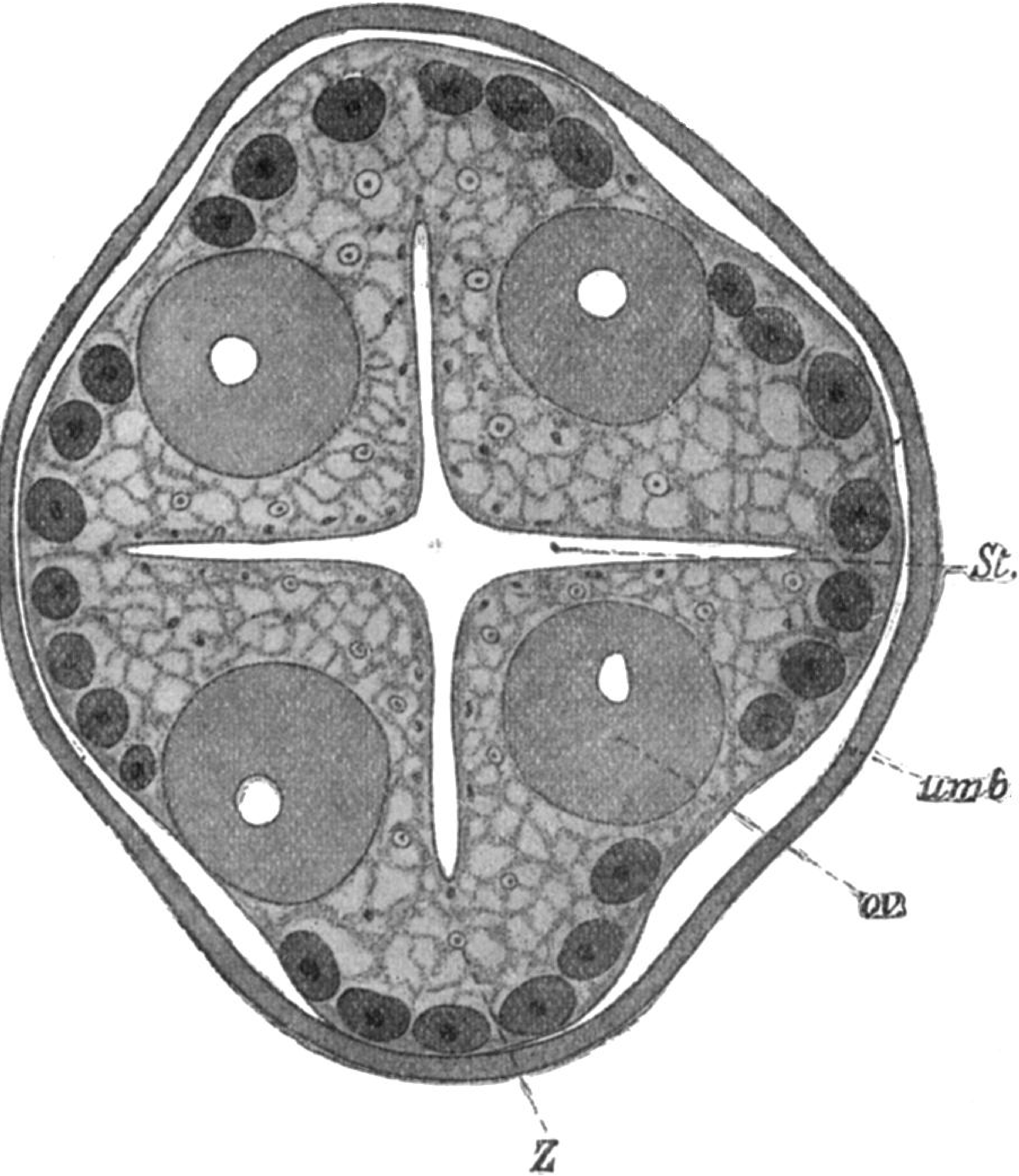


FIG. 3.



FIGS. 4—9.

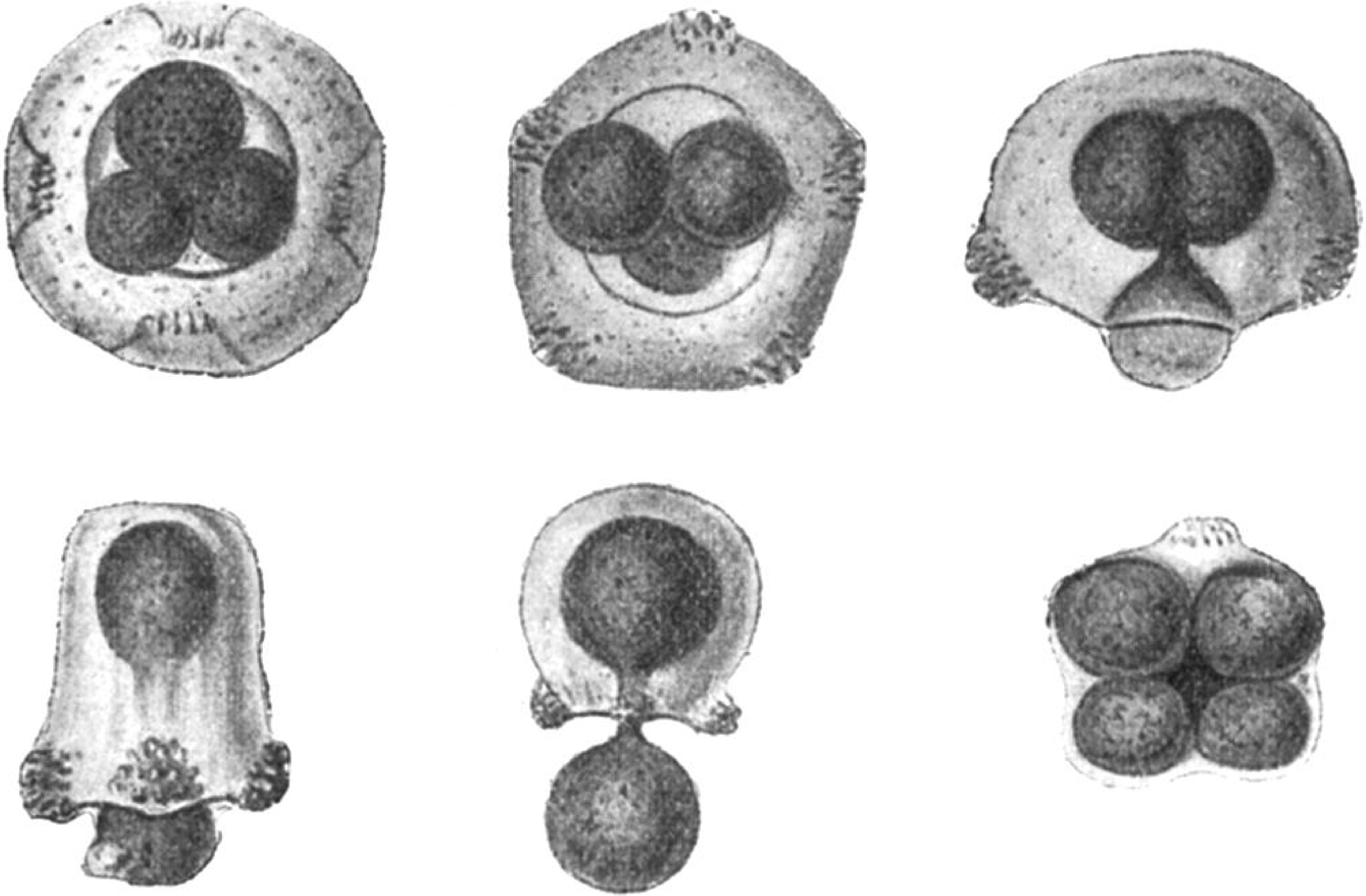


FIG. 10.